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Effectiveness of Android-Based 3D Applications to Support Students' Mental Models on Molecular Geometry Material

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ABSTRACT

The learning media in the form of Android needs an effectiveness test to find out its effectiveness in material implementation at school. The purpose of this research was to find out the efficacy of 3D Android-based Based Chemistry Learning Media in molecule form material on students' mental models if compared to common learning media used at the school. This research was conducted at MA Darul Hikmah Pekanbaru. The research method used was a mixed method with the research design of The Explanatory Sequential Model. The samples were selected based on the technique of simple random sampling on grade X students of MA Darul Hikmah Pekanbaru. The research instrument used was a two-tier diagnostic test supported by interviews. The data were processed by using the hypothesis test and N-Gain test. The research results showed that overall, the student's mental model in the experimental group that used 3D Android Application Learning Media had 63% intact mental model and 37% alternative mental model. In comparison, students in the control group obtained 22% intact mental model and 78% alternative mental model. The research findings also showed the hypothesis test, which obtained sig. Value (2-tailed) = 0.000, which means 0.000<0.05 until Ha is accepted and Ho is rejected. Based on the N-Gain test, the experimental group showed quite an effective category, with the percentage of N-Gain amounted to 60%. This showed that media updates and material enrichment are required in order to increase the students' mental model.

INTRODUCTION

Chemistry is a branch of natural science that has concepts. The concept of chemistry is known as the "Chemistry Triplet", meaning that chemistry includes three levels of representation: macroscopic, submacroscopic, and symbolic (Supriadi et al., 2023; Pikoli et al., 2022). Images or real objects that can be observed directly are called the macroscopic level. Images or real objects that can be seen directly are at the macroscopic level. The submacroscopic level is the actual level of depiction, but at the particle level, meaning some things need to be explained, including how the shape of the particles changes during a chemical reaction. The symbolic level is where the depiction uses analogies, mathematical equations, and graphs (Hikmah et al., 2022; Wafi Lutfia & Putra, 2020).

The three levels of chemical representation must be present in chemistry learning to produce a complete understanding of chemistry (Siregar & Kurniawati, 2022). To create meaningful learning in chemistry learning. This is realized if students can connect the three levels of representation in learning chemistry. The three levels of representation namely macroscopic, submacroscopic, and symbolic are often known as mental chemistry or generally known as student mental models (Pikoli et al., 2022; Azzahra & Suherlin, 2022; Hikmah et al., 2022). Mental models are an understanding of the three levels of representation. A person's concept or idea used to describe a phenomenon is called a mental model. When students can connect the three levels of chemical representation on the material presented, then the student has a complete mental model (Ummah et al., 2022; Khafsoh, 2022). However, students do not have a complete mental model if they cannot make connections between the three levels of chemical representations of an idea (Siregar & Kurniawati, 2022).

These three chemical concepts are interconnected with each other and this is what is depicted in the mental model. Mental models are a product of learning. This is because mental models can provide information on students' concept understanding. Knowing the mental models of students can allow teachers to know the understanding, description and ease and difficulty of students in understanding the concepts learned. Mental models can represent ideas or images in one's mind in describing a phenomenon (Murni et al., 2022; Laili et al., 2021). A student's mental model can reveal the extent of their understanding of a concept, especially an abstract one. Students' mental models for teachers play an important role in determining suitable learning strategies in further learning, teaching materials, or media used so that student's understanding of a concept becomes a unified whole (Putri & Muhtadi, 2018; Rachmawati & Sukarmin, 2022).

But in reality, based on previous research, chemistry learning that takes place so far is more easily understood by students at the macroscopic level, while the other two levels, namely submacroscopic and symbolic students are still few who can understand it (Supriadi dkk., 2023; Pikoli et al., 2022). This also happens in Madrasah Aliyah Pekanbaru on molecular geometry material, where students still have difficulty imagining the real molecular geometry due to the lack of effective selection of learning media on molecular geometry material; one example of the media used is blackboard media, so the shape of the molecule can only be seen in 2 dimensions so that students have difficulty imagining how the real molecular geometry (3D) (Malihah et al., 2021). To easily understand the abstract material on molecular geometry material, it is necessary to have a learning media that aims to help students understand abstract material and connect between the three levels of chemical representation (macroscopic, submacroscopic, and symbolic). So that the existence of learning media can form a complete mental model in students (Novaliendry et al., 2020). This is in line with previous research by Erlina Azmi siregar who said in her research that the use of android-based learning media can form a complete mental model in students (Siregar & Kurniawati, 2022).

Molecular geometry 3D application is one alternative that can be used as an effective learning media on molecular geometry subject matter. Molecular geometry 3D application media has advantages compared to other learning media that can display the geometry of molecules in three dimensions, explain the position of PEB & PEI in molecules, and explain the type of molecule along with examples. Learning media application 3D molecular geometry can also be implemented in the learning process so as to facilitate students in understanding the material molecular geometry, and teachers can also explain in detail how molecular geometry is real (Arif, 2018). So that students can imagine the geometry of molecules in real without guessing how molecular geometry, and with the existence of 3D learning media based on Android, can form a mental model that is intact in students. However, 3D application media molecular geometry needs to know its effectiveness in the development of mental models of students on the subject matter of molecular geometry.

METHODS

Research Design

The research method used is mixed method research, which combines qualitative and quantitative data. The use of mixed methods is because this research explains quantitative and qualitative data. In this study, quantitative data is in the form of pre-test and posttest data, while qualitative is in the form of analyzing students' mental models obtained from quantitative data. This qualitative data is also supported by interviews. Therefore, this research uses Sequential Explanatory research design (Kurniawati, 2019). The stages can be seen in Figure 1.

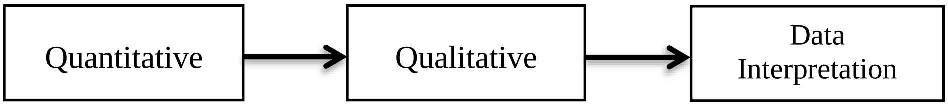

Figure 1. Exploratory Sequential Stages

In this design there are stages, namely, in the first stage researchers collect quantitative data in the form of pretest and posttest data, the second stage researchers collect and analyze qualitative data based on the results of the first stage, and in the third stage the data interpretation process is carried out based on the previous process, namely the initial and second stages. Meanwhile, the quantitative method uses a quasi-experimental design.

Research Target

The population in this study were all students of class X MA Darul Hikmah Pekanbaru, the sample used was 15 students from class X1 as an experimental group who were treated with the help of learning media Bentuk Molekul 3D Simulasi - Aplikasi di Google Play based on android on molecular geometry material and 15 students from the control group, namely class X3. The sampling technique used is simple random sampling.

Research Data

The data collected in this study are quantitative data (pretest and posttest data) and qualitative data (analyzing students' mental models obtained from pretest and posttest data). The data collection technique uses (1) a two-level diagnostic test, which is a tool to measure or determine the concept of students' understanding of the concept of a material being studied where this question has two levels where the first level consists of questions in the form of multiple choice, 1 correct answer 3 or 4 wrong answers. At level 1 is useful for knowing the concept of student understanding, while the second level is the reason that refers to the first level answer, at this second level it is useful for knowing the student's mental model. (2) The interview used in this study is a structured interview, which is a type of interview that uses interview guidelines that are arranged systematically to see how the learning media used can support students' mental models, each student is interviewed for about 5 minutes. (3) documentation aims as visual evidence that the research was conducted.

Research Instruments

This research instrument uses a two-tier diagnostic test totaling 19 items about molecular geometry material. This two-tier diagnostic test was carried out in two stages, namely pretest and posttest. This instrument has passed the stages of (1) content validity test where researchers conducted content validation to validators, namely two lecturers of chemistry education at UIN Suska Riau which aims to see the linkage of two-tier question indicators with TP (Learning Objectives), (2) empirical validity test tested on class XI students and obtained 19 valid items, this question was used during the study, and (3) reliability test obtained a reliability value of 0.87 with a high category.

Data Analysis

In this study, the data were analyzed using normality test, homogeneity test, hypothesis test, and N-Gain test. The hypothesis test used is the t-test which aims to see whether the Android-based 3D application media can support students' mental models, then the N-Gain test which is used to see the extent of the effectiveness of Android-based 3D media on students' mental models. In this study there are quantitative and qualitative data, where quantitative data is obtained from pretest and posttest scores. Then qualitative data is to analyze the mental model of students on molecular geometry material whether it has a complete mental model or an alternative mental model from the previous data (quantitative data). This is in accordance with the stages of Sequential Explanatory research design.

RESULTS AND DISCUSSION

This research went through two tests, namely pretest and posttest. After testing the experimental and control group groups, N-Gain data was obtained. This can be seen in Figure 2. Where in the experimental group the N-Gain value in the high category was 23 students, while in the medium category, there were nine students. Whereas in the control group there were 18 students in the medium category and 12 students in the low category. This is presented in Figure 2.

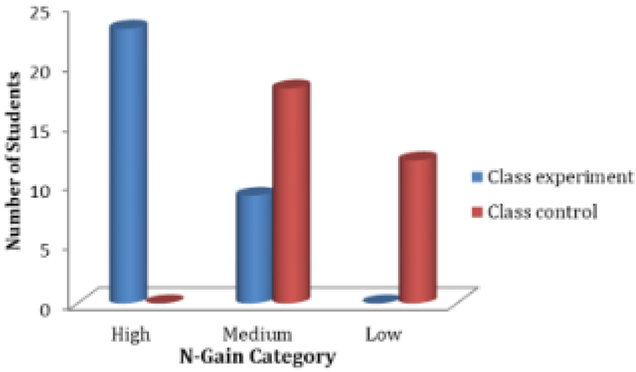

Figure 2. N-Gain category of Experimental & Control group

When viewed from the N-Gain interpretation category, it shows that the N-Gain in the experimental group using Android-based 3D application media is fairly effective, with an N-Gain value of 72%. This is because the 3D molecular geometry application media can support students' mental models. After all, the application displays the geometry of molecules in real 3D clearly and shows images of molecular geometry attractively. The results of student interviews also support this. Where from the results of these interviews, students are very interested in learning to use 3D molecular geometry applications because it can facilitate students in understanding molecular geometry material and seeing the geometry of molecules in real. Meanwhile, the control group with conventional learning showed an N-Gain value of 60%, which means that learning is fairly effective on students' mental models (Rahmi et al., 2020). This is presented in Table 1 as follows.

Table 1. N-Gain Interpretation Categories

Class	Percentage (%)	Interpretation
Experiment	72%	Fairly Effective
Control	60%	Fairly Effective

Based on Table 1 and Figure 2 show that this android-based 3D application media can influence students' mental models because the learning media used by researchers includes three levels of representation, namely the submicroscopic level, macroscopic level, and symbolic level (Anggi Wulandari & Fakhriza, 2021). Where these three levels of representation are needed in learning, which aims to build students' mental models, based on the recapitulation of the two-tier diagnostic test in the experimental group and control group, can be seen in Figure 3. Following treatment with 3D learning media based on Android, 63% of students in the experimental group had a scientific mental model, 34% had a partially correct mental model, and 3% had a special misconception mental model. The results showed that the percentage of students' mental models in the experimental group showed that scientifically correct mental models dominated students' mental models. In contrast, the control group was more dominated by partially correct mental models. The control group, without using 3D application media, has a scientific mental model with a percentage of 22%, and the rest is an alternative mental model consisting of a partially correct mental model with a percentage of 69%, a special misconception mental model of 6%, and a mental model of no answer as much as 3%. The following is the percentage of mental models of experimental and control group students in Figure 3.

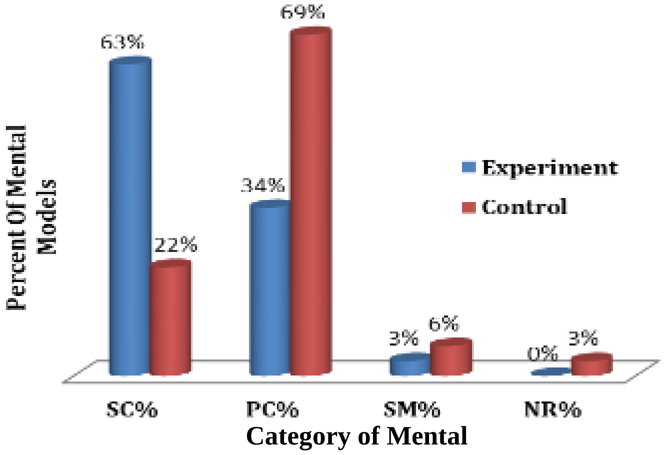

Figure 3. Students' Mental Model Analysis Score.

The data acquired from the experimental group and the control group show a significantly different comparison, at 22% and 63%, respectively. A complete mental model cannot be obtained 100% of the time; rather, it requires a process of training and exploring students' abilities and connecting the three levels of representation in the application of the Chemistry learning process to achieve a complete mental model. This is why, even though they still have alternative mental models, the achievement of the mental model score obtained is included in the high category based on the scoring of the two-tier diagnostic test.

While the comparison of alternative mental models between the experimental group and the control group has a distant comparison of 37 : 78%. This is because students are still dominated by alternative mental models, namely Partially Correct, Specific Misconception, and No Response (NR). Based on the answers of students in the control group, most students in the control group had difficulty in connecting the theory of the number of electron pairs with molecular geometry (Hurrahman et al., 2022). One example is in determining the molecular geometry of water (H_2O) which should be the molecular geometry of the V shape but some students still answer or describe the molecular geometry of water (H_2O) which is linear shape. This explains why students in the control group have alternative mental models that are significantly more prominent than students in the experimental group because of their lack of ability to connect the three levels of representation.

Students' mental models in the experimental and control groups can also be seen from the classification of students' mental model levels. The results of this study found the fact that students in the experimental group had mental models with a more dominant achievement score category compared to students in the control group. The control group's poor accomplishment category score resulted from the pupils' inability to make connections between the three levels of representation to create a comprehensive mental picture. While experimental group students through the use of 3D applications based on Android have been accustomed to connecting three levels of chemical representation through learning models, thus forming a comprehensive mental model in the process (Putri & Muhtadi, 2018; Setiawaty et al., 2023). This can be seen in Figure 4.

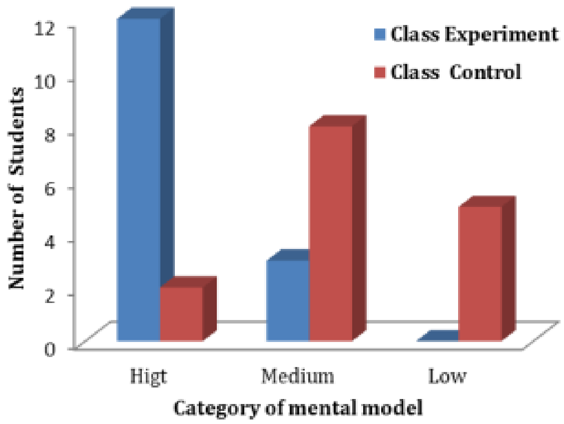

Figure 4. Classification of Mental Model Levels

Based on the description of the value of students' mental models through a two-tier diagnostic test with a total of 19 questions, it can be seen in Table 2.

Table 2. Description of Students' Mental Model Score Experiment and Control group

Model Mental	N	Min	Maks	Mean	Std. Dev
Class Experiment	15	70	90	84.53	6.069
Class Control	15	50	82	63.87	9.680

The description of the value data above shows that the experimental group test scores are in the high category, where it is explained based on the mean value in Table 2 that the experimental group has a value weight of 84.53. It can be concluded that the value of 84.53 is included in the high category. The control group is in the medium category as indicated by the mean value of 63.87 in Table 2.

In addition, students' mental models can also be seen from students' achievements per question indicator and the three representative levels, namely macroscopic, submacroscopic, and symbolic levels. Based on the submacroscopic level, it states that students in the experimental group have a submacroscopic representation level that is superior to students in the control group. This is because students in the experimental group were able to explain their understanding of molecular geometry through images and identify molecular geometry from an image, besides students in the experimental group also could connect the concept of the number of electron pairs with the shape of the molecule and students in the experimental group could also answer questions well on submacroscopic level questions because, in the learning process, students in the experimental group used 3D learning media based on android. In using this media, students are accustomed to learning abstract material (molecular geometry) to be more easily understood by the images and detailed explanations in the media used, so students are accustomed to connecting the concept of the number of electron pairs to the shape of the molecule.

Students in the control group (without using 3D media) are more likely to find it difficult to connect the concept of the number of electron pairs with the shape of the molecule because students are only able to imagine how a molecule looks like. This difficulty eventually caused students in the control group to tend to memorize during the learning process. This memorization will only hinder students in meaningful learning because students only focus on memorization without understanding the concepts they learn. This submacroscopic level can be seen in question numbers 1,2,3,4,5,8,9,10,11,12,13,14,15,16,17,18, and 19. This is presented in Figure 5, as follows.

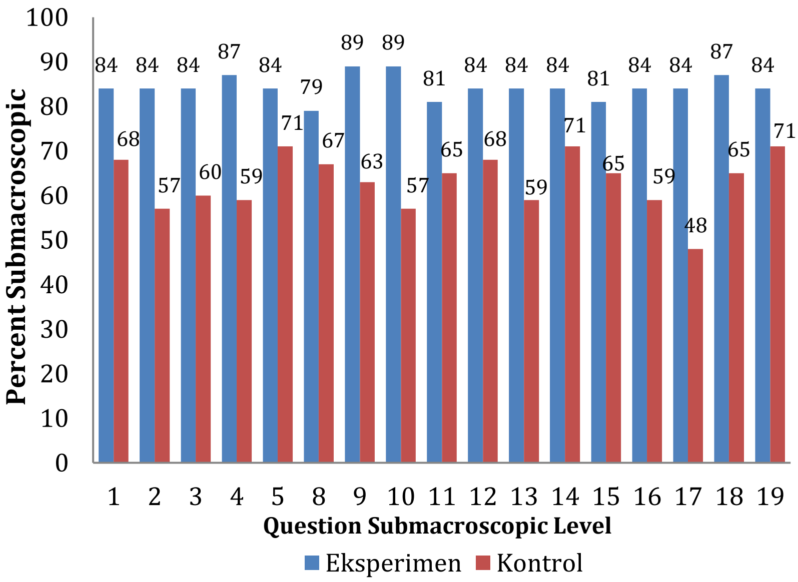

Figure 5. Submacroscopic Level

If observed from the data on the symbolic level results in questions number 6 and 7 where this question asks about the geometry of molecules based on the number of electron pairs, for example the molecular geometry of SF6. From this question, it is known that most students only know the geometry of the molecule without knowing the symbolic form of the molecule based on the number of electron pairs theory. Therefore, in answering this question, students tend to be partially correct and experience misconceptions in certain parts, for example students can guess the geometry of the molecule but cannot say how many PEI and PEB. So, this is what causes students in the control group at the symbolic level of students in the control group to get a low percentage when compared to experimental group students. While the experimental group students are accustomed to studying molecular geometry material through 3D application media based on Android so that the understanding of students in understanding the material has been able to reach the symbolic level, because the 3D molecular geometry application displays the geometry of molecules in real even the shape of PEB and PEI can be seen in real. Therefore, the percentage of symbolic level in experimental group students is higher than the control group. This can be seen in Figure 6, as follows.

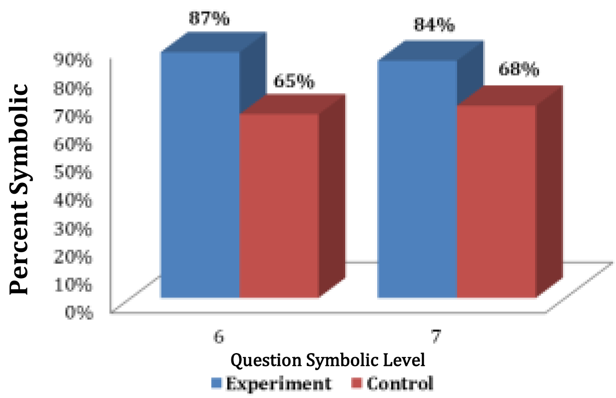

Figure 6. Symbolic Level

This study also shows data on the achievement of student scores based on item indicators, there are five indicators, namely (1) determining the shape of a molecule from a picture based on the theory of the number of electron pairs, (2) identifying the shape of a molecule based on the theory of the number of electron pairs, (3) determining the number of PEI and PEB electron domains of a molecule, (4) describing the shape of a molecule based on the theory of the number of electron pairs, and (5) determining the hybrid orbitals that occur in molecules based on the theory of the number of electron pairs of matter. In the experimental group, the highest is in the indicator of question number 1, namely determining the shape of a molecule from a picture based on the theory of the number of electron pairs found in question number 14 with a percentage of 93%, as well as indicator number 3, namely determining the number of PEI and PEB electron domains of a molecule in question number 13 with a percentage of 93%. This is because the experimental group uses android-based 3D learning media that can help students see the shape of the molecule. Because the 3D media displays clear images of molecular geometryalong with clear PEI and PEB bonds so that initially the molecular shape is abstract to become real so that students can connect the three levels of representation in learning. However, in the experimental group, the percentage of low student scores was in question number 12 with a percentage of 83% on the indicator of question number 5, namely determining the hybrid orbitals that occur in molecules based on the number of electron pairs theory. This is because some students still have difficulty in calculating the number of PEB and PEI even though there is already the help of 3D learning media so a small number of students still have difficulty determining the hybrid orbitals of molecules. In addition, other factors are the limitations of accessing 3D media and time constraints, with these limitations causing low student scores on question number 5 indicators.

In the control group, the high value is in question number 14 with a percentage of 81% on indicator number 1, namely determining the shape of a molecule from a picture based on the theory of the number of electron pairs. While the value with a low percentage is in question number 7 & 16 with a percentage of 62% on indicator 4, namely describing the shape of a molecule based on the theory of the number of electron pairs, question number 9, 11 & 17 with a percentage of 62% on indicator 3, namely determining the number of PEI and PEB electron domains of a molecule.

His research also looked at whether the experimental and control groups' pupils' mental models differed from one another. Based on the data obtained, the sig value (2-tailed) = 0.000, which means $0.000 < 0.05$. This shows that there is a significant difference in students' mental models between students who learn with Android-based 3D applications and pupils who study without using material from 3D applications for Android. This demonstrates that there is a notable variation in student mental models between students who learn with Android-based

3D applications and pupils who don't use Android-based 3D application media in their education.

So this research shows that this android-based 3D application media can influence students' mental models because the learning media used includes 3 levels of representation, namely submicroscopic, macroscopic, and symbolic levels (Wulandari & Fakhriza, 2021). Where the three levels of representation are needed in learning which aims to build students' mental models as a whole. Accustoming students to learning learning material with these three levels of representation can reduce the incompleteness of student understanding which results in students' chemical mental models which tend to be incomplete and with this android-based learning media can increase student motivation in learning so that students are more active in the learning process. Because this Android-based 3D application media displays real molecular geometry, and displays interesting images, and in this application explains in detail how this molecular geometry can be formed and displays PEI and PEB clearly and explains the position of PEI and PEB that can affect the angle or shape of a molecule. So that with the implementation of 3D media can facilitate students in understanding the material molecular geometry, so that the formation of a complete mental model of students.

This is in line with research in his research states that the advantages of 3D learning media based on Android are that it can stimulate students to think actively in learning because the 3D application based on Android presents the material as a whole and systematically, making it easier for students to understand, besides that 3D media based on android can display material that is abstract in a clear and real way, so that students master learning objectives well (Rassyi et al., 2023; Rohmah & Hidayah, 2022). The advantages of 3D learning media based on Android can have a significant positive effect on student learning outcomes that are much better (Hia et al., 2022; Mindayula et al., 2021; Subagiyo, 2021) Although in its effectiveness the media is only able to reach the moderately effective category, this is because during the learning process that takes place, researchers divide students into several groups, each group is given one cellphone so that the use of media used by students is limited because only one cellphone is available per group so that students must take turns in using the 3D application media based on android in the learning process (Yamtinah et al., 2023). Although the effectiveness of the media only reaches the moderately effective category, the media can still help students in the learning process. Students get immediate access to the offered content, which is complemented by attractive images about the content, thus making students understand more and clearly the material presented and appear more real.

CONCLUSION AND RECOMMENDATIONS

The results showed that Android-based 3D learning media was fairly effective on students' mental models. This is indicated by the N-Gain interpretation category in the experimental group of 72%, which means that the Android-based 3D application media is fairly effective on student mental models on shape material. In comparison, the control group based on the N-Gain interpretation category of 60% is fairly effective. In addition, the difference that needs to be considered is the mental model of students in the experimental group and control group, where the experimental group is dominated by an intact mental model, which is 63%. At the same time, the control group was dominated by alternative mental models, which was 78%. With a significant difference in mental models, it means that this android-based 3D learning media can affect students' mental models of molecular geometry material. So, this research can be used as a reference for choosing effective learning media on molecular geometry meters as well as a reference to determine the mental model of students on molecular geometry material. Still, of course there is a need for the development of the completeness of the existing content on this media that aims to complete the shortcomings that exist in the media so that the future will be even better.

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